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Seed Rain Patterns During Early Recovery on a Strip-mined Site in Southwestern Wyoming

Hal W. Gordon
Utah State University

SEED RAIN PATTERNS DURING EARLY RECOVERY ON A STRIP-MINED SITE IN SOUTHWESTERN WYOMING

By

Hal W. Gordon

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Utah State University
College of Natural Resources
Department of Range Seience
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INTRODUCTION

Revegetating surface-mined soils of the western United States is a major problem facing natural resource managers today. The Surface Mine Reclamation and Conservation Act (SMRCA, Public Law 95-87) requires that the operator:

> "...establish on the regraded areas, and all other lands affected, a diverse, effective and permanent vegetative cover of the same seasonal variety native to the area of land to be affected and capable of self-regeneration and plant succession at least equal in extent of cover to the natural vegetation of the area..."

Historically, most of the coal produced in the U.S. came from the eastern states; recently, production has shifted to the West (U.S. Dept. of Energy 1982). The reason for this shift in coal production is economic. Net production costs are lower and higher recovery rates are possible in the West where the coal is closer to the land surface. Effectively revegetating disturbed areas will become more important as strip-mining increases in the western states.

Various methods exist to revegetate disturbed sites. Seedlings can be planted on the site (Everett 1980) or the site can be reseeded (DePuit and Coenenberg 1979). However, commercially available native seed is very expensive. Many species and their ecotypes are not commercially grown and natural seed sources are scarce or difficult to harvest. Some vegetation is established from seed reserves in topsoil replaced on the mined area (Beauchamp et al. 1975, Brophy 1980, Johnson 1984). Seeds for all successional stages are often found in soils of mesic habitats (Livingston and Allessio 1968, Miles 1979). This may not be true for arid environments or where the soil has been deeply disturbed (Budd et. al. 1954, Lippert and Hopkins 1950). Unfortunately, seed survivorship in stored topsoil has not been high enough to meet state and federal revegetation standards (Howard and Samuel 1979, Johnson 1984). Most revegetation studies are concerned with human management of revegetation while few studies deal with natural revegetation of disturbed areas (Czapowski 1976).

The success of establishing native vegetation on mined sites is often dependent on the ability of native seeds to move onto the disturbed area. Wind is thought to be the major seed dispersal agent on many sites; however, animals, water and gravity may also be important (van der Pijl 1972). Although knowledge of natural seed movement over time and space onto a site (seed rain) could be very useful to managers attempting to meet the requirements of SMRCA, investigations of seed rain are few and diverse.

Plants growing on a site at one point in time represent only those species which germinated and survived under recent environmental conditions (Harper and White 1971). Seed rain, however, may represent a much larger pool of plant species that have the potential of germinating and surviving on a site. Few studies have dealt exclusively with seed rain.

Everett (1983) defined seed rain as the number of filled seeds arriving at the soil surface. He examined seed rain on pinyon-juniper sites before and after clearcutting and found that the number of seeds and species arriving on a site varied between years. Seed rain was greater on clearcut plots and mesic sites than on uncut and dry sites. Archibold and Hume (1983) defined seed rain as the number of seeds entering specific sites. Archibold (1980) studied seed input on strip-mined wastes in Saskatchewan, and found that vegetation arising from seed rain provided adequate vegetal cover. He attributed the lack of cover in some areas on the site to removal or deterioration of seeds. Archibold and Hume (1983) also studied seed input into fallow fields in Saskatchewan and found seed rain to be a major contributor to future weed communities. Hassan (1983) examined seed rain on a sagebrush-grass site following wildfire and was unable to detect differences between burned and unburned sites. Vasek et al. (1975) found availability of seeds and time of soil disturbance to influence vegetation development on powerline corridors in the Mojave Desert. Wagner et al. (1978) studied succession and seed dispersal on strip-mined sites in New Mexico. They found that untreated mined areas had a slow rate of vegetal recovery and were dominated by annual and short-lived perennial plant species. They also found greater species diversity in adjacent, unmined areas than was found on the mined sites. Karr (1968) found that sixty years were required for a strip-mined site in Illinois to naturally develop into the shrub-forest stage.

The general objective of this study was to monitor seed rain on a mined site in the sagebrush-steppe region. Specifically, I wanted to determine (1) which unplanted species arrived on the disturbed site and in what numbers, (2) if spatial variation in seed rain occurs and (3) the importance of seed rain on the site.

METHODS

The study site is located in southwestern Wyoming near Kemmerer (41°45'N, 100°35'W) on the Elkol-Sorenson Mine, owned and operated by the Pittsburg and Midway Coal Mining Company. The area, at an elevation of about 2100 m, was classified by West (1983) as western intermountain sagebrush steppe, and by Vale (1975) as the sagebrush-bunchgrass association. The precipitation, which is about half snow and half rain, averages 22.6 cm/yr (40-year average). Monthly average temperatures range from -8°C in January to 17°C in July (Parmenter and MacMahon 1983). No long-term data exist for wind, but it is predominantly from the west.

The site is dominated by two hills with prominant ridges running in a north-south direction and increasing in elevation from south to north. The average slope of the hills is 15% and slope lengths are approximately 50 meters. The site was recontoured with spoil. Topsoil was applied in 1981, the majority of which was stored topsoil; in some locations fresh topsoil was applied. The area west of the mined site is undisturbed and nearly all the plants found there are native to this region. This area was assumed to be the principal seed source, being on the windward side of the mined site. There is also a native area east of the mined site where seeds may have originated. The topsoil has been classified by Howard and Samuel (1979) as an Ustic torriorthent with a clayey, montmorillonitic, calcareous, frigid, shallow family. Plant communities were relatively stable and there were few environmental disturbances before european man arrived in the area (May et al. 1971). Prior to mining, the site was primarily used for wildlife habitat and livestock grazing; the same is prescribed for postmining use (May et al. 1971).

One hundred and fifty-five plant species (Table 1) from 131 genera were observed growing in the native area surrounding the study site (Alan T. Carpenter and N. E. West, unpublished data). A list of plant species growing on the mined site (Table 2) was obtained from an associated study (Pat Johnson, personal communication).

Five plant species were planted on the mined site in early spring 1982. These include three shrubs, Artemisia tridentata, Chrysothamnus vicidiflorus and Atriplex gardneri; one perennial forb, Hedysarum boreale; and one perennial grass, Agropyron smithii.

The term 'seed rain', as used in this report, refers to the number of seeds reaching the soil surface from a seed source area (i.e., parent plant). Seed traps were used to collect seeds; the majority of seeds were expected to be transported by wind. Seed traps were constructed from 15 cm diameter funnels with a cotton ball and string wick placed at the bottom to facilitate water drainage. Each seed trap was filled with washed river gravel. A 15 cm section of 15 cm diameter irrigation pipe was placed in the ground for each trap, having its upper edge flush with the soil surface (Figure 1). The funnel was then placed in the irrigation pipe so that the surface of the gravel in the funnel was approximately flush with the soil surface, so as to reduce air turbulence. This seed trap design was tested by Johnson (1984, unpublished manuscript); she concluded that the traps would capture a quantity of seeds comparable to the number retained by the soil surface. Also, because of the large amount of wind-blown material on the Kemmerer site, the extended time the seed traps would be in place, and the large number of seed traps to be used, the seed trap design chosen was selected over several other designs available (e.g., Archibold 1980, 1983) including one using a sticky non-drying material (Werner 1975). This seed trap method of estimating seed rain may not account for seeds that gather in the canopy of the vegetation and for seeds dispersed by animals. Seed traps were placed at 5-meter intervals along three parallel transects running west to east, each begining at least 40 meters into the undisturbed area to the west of the mined site and extending completely through the mined area. The west-east orientation of the transects roughly parallels the prevailing wind direction and the transects were situated to ensure representation of high, mid and low elevation wind patterns. The distance between each transect was approximately 100 meters. There was a total of 255 seed traps. Seed-trap transects were established during early summer of 1982. The contents were collected during the fall of 1982 and spring of 1983. The second collection accounted for seeds distributed in the late fall and winter from late maturing species. Each seed-trap sample was placed in a labeled paper bag and kept in cold storage to reduce seed shrinkage and germination until seeds could be extracted and identified.

Seeds were extracted from the gravel, litter and soil of each seed trap sample by hand sifting through a series of three screens. Mesh sizes were 10 mm, 1 mm and 0.3 mm. Debris remaining on each screen was examined under a 10X binocular microscope. Material less than 0.3 mm was not searched because the smallest mature seed was expected to have a diameter greater than 0.5 mm. Seed traps that contained dried mud were washed in a solution described by Malone (1967), then dried and separated as described above. Seeds were identified to species using a seed herbarium from the site, figures in Seeds of Woody Plants in the United States (USDA 1974), and figures in Vascular Plants of the Pacific Northwest (Hitchcock et al. 1971).

Analyses

This seed rain study was a non-randomized block design with three blocks (transects) and six locations: 1) west native area, 2) west slope of west ridge, 3) east slope of west ridge, 4) west slope of east ridge, 5) east slope of east ridge and 6) east native area. The boundaries between the locations were the interfaces between strip-mined and nonstrip-mined land on both the east and west sides of the mined site as well as the two ridgetops and the gulley between the two ridges.

The null hypothesis to be tested was that seed rain at the site is random (i.e., that there were no differences between transects and locations with regard to the total number of species per seed trap). The alternative hypothesis was that seed species distribution on the site is not random. The lack of randomization in seed trap locations resulted in a loss of power in statistical analysis. However, because this was a pilot study and the data can be considered exploratory, randomization tests were considered the most appropriate method of analysis (Romesburg 1985).

Analysis of these data was made with the understanding that inferences should only be applied to the study site.

The number of plant species with seeds (seed species) found in the seed traps was compared among seed-trap locations. This was done by averaging the number of seed species found in four consecutive seed traps for each location on each transect.

Seed produced on the mined site was differentiated from seed produced off the mined site by comparing the seed species found in the seed traps to the list of plant species growing on the mined site. If seed was found on the mined site and a plant of the same species was not growing on the mined site, it was assumed that the seed came from the native area. Also, seed species were assumed to have originated from the native area if plants of that species growing on the mined site did not flower or produce seed.

Results

A total of 9,022 seeds were found in the seed traps during the fall of 1982 and spring of 1983, with a range of 0 to 799 seeds per seed trap. Of these, 95.5% were seeds of annual forbs, 1.6% of shrubs, 1.5% from perennial forbs, 0.8% of annual grasses, 0.4% of perennial grasses and 0.1% of unidentified species.

The results of the randomization tests using CLASSTEST (Romesburg 1985) with Ward's E statistic and nonstandardized data, using 1,000 trials, result in a P value of 0.007 (95% confidence interval is $.002 < P < .012$). Thus, the null hypothesis that seed species distribution on the site is random was rejected and the alternative hypothesis accepted.

Seeds of thirty-five species were found in one or more seed traps in both the native and mined areas (Table 3). Seeds of twenty-four plant species were found in the seed traps on the mined site only (Table 4), including seeds from six plant species which were not found growing on the site. Of the six species, five were perennial forbs and one was an annual forb. Thus, these species were assumed to have originated from off the mined site. Five additional species were also assumed to have originated from off the mined site because plants of those species (growing on the mined area) were not observed to flower or produce seed. Thus, a total of eleven of the twenty-four seed species found in the seed traps on the mined area were assumed to have been produced off the site (Table 4). The other 13 were growing and producing seed on the mined site.

The total number of seed species found in the seed traps was quite variable across the mined site (Figure 2). It seems that topography plays a major role in determining where seed is deposited on the site. The number of species represented in the seed traps was lowest near the two ridgetops and highest between the two ridges on the lee side of the west ridge. The number of seed species found in the west native area was similar to that of the east native area.

The distribution of seeds from species produced off the mined site was very similar to the distribution of all species, regardless of their origin (Figure 2). They were again concentrated between the ridges and almost nonexistent on the ridgetops.

The distribution of seeds from each species was highly variable across the site (Table 5). For example, the most common seed found was from *Salsola iberica*, which had its highest seed densities on the east slopes of the west and east ridges and its lowest densities in the west native area. *Descurania sophia* had a high seed density on the east slope of the west ridge, but few seeds were found elsewhere. Seed from *Polygonum aviculare* was found throughout the site with the highest densities on the east slopes of both ridges. Of the seed assumed to have been produced off the mined site, Poa scabrella had the highest density with 768.34 seeds per square meter on the east slope of the west ridge. Seed of this species was not found at all on the west slopes of both ridges.

Discussion

Determining where seed came from was essential to this study. The seed rain on the mined site was comprised of seed from two sources, 1) seed produced on the site and 2) seed produced off the site. Vegetation growing on the mined site the first year after recontouring resulted from soil-seed reserves, plant fragments in the replaced topsoil, seed rain, planted seeds and shrub seedlings. During the fall of 1982 and the spring of 1983, seed traps contained seed of annual species produced on the site and seed which migrated onto the site. Perennial species growing on the site were not observed to produce seed during 1982. Thus, seeds of perennials found in the seed traps must have migrated onto the site. Annual plant seeds found in the traps the first year may have been produced on the site or were transported onto the site; it was difficult to differentiate between the two sources. Both the seeds produced on the site and those which were transported onto the site contributed to the seed rain the first year after reclamation.

Topography seems to play a greater role in seed deposition than proximity to the native undisturbed vegetation. The majority of seeds found on the mined site were found on the lee side of the west ridge, thus it would appear that wind plays a major role in seed dispersal in this type of environment.

The only place on the mined site where planting desirable species may not be required would be on the lee side of the ridges. Most of the seeds tend to collect there. The west-facing slopes did not receive appreciable amounts of desirable seeds and the ridgetops even less. Based on the results of this study, the mine operator, with budget and time constraints, should concentrate his revegetation efforts on these two areas.

Table 1. Plant species growing near the mined site.

GRASSES:

AGROPYRON SP
A. CANINUM (L.)BEAUV.
A. DASYSTACHUM HOOK.
A. SMITHII RYDB.
A. SPICATUM (PURSH)SCRIBN.
A. SPICATUM VAR. INERME HELLER
AVENA SP
A. FATUA L.
BROMUS SP
B. ANOMALUS RUPR. EX FOURN.
B. INERMIS LEYSS.
B. JAPONICUS THUNB.
B. TECTORUM L.
CAREX SP
C. DOUGLASII BOOT.
C. HOODII BOOT.
C. NEBRASCENSIS DEWEY
C. PETASATA DEWEY
C. PRAEGRACILLIS BOOT.
C. STENOPHYLLA WAHL.
C. VALLICOLA DEWEY
C. OCCIDENTALIS L.H.BAILEY
ELEOCHARIS SP
E. PALUSTRIS (L.)R.&S.
ELYMUS SP
E. CINEREUS SCRIBN.
FESTUCA SP
F. IDAHOENSIS ELMER
HORDEUM SP
H. BRACHYANTHERUM NEVSKI
H. JUBATUM L.
H. VULGARE L.
JUNCUS SP
J. BALTICUS WILLD.
J. HALLII ENGELM.
KOELERIA MACRANTHA (LEDEB.)SHULT
LEUCOPOA KINGII (WATS.)WEBER
MELICA BULBOSA GEYER EX PORTER
MUHLENBERGIA SP
M. RICHARDSONIS (TRIN.)RYDB.
ORYZOPSIS SP
O. EXIGUA THURB.
O. HYMENOIDES ROEM.&SCHULT.
O. SWALLENII HITCH.&SPELL.
POA SP
P. FENDLERIANA (STEUD.)VASEY
P. GLAUCIFOLIA SCRIBN.&WILLIAMS
P. JUNCIFOLIA SCRIBN.
P. NEVADENSIS VASEY EX SCRIBN.
P. PRATENSIS L.
P. SANDBERGII VASEY
P. SCABRELLA (THURB.)BENTH.
PUCCINELLIA SP
P. NUTTALLIANA (SHULT.)HITCH.
SITANION SP
S. HYSTRIX (NUTT.)SMITH
STIPA SP
S. COLUMBIANA MACOUN
S. COMATA TRIN.&RUPR.
S. LETTERMANII VASEY
S. PINETORUM JONES
S. OCCIDENTALIS
S. OCCIDENTALII THURBER EX WATS.

SHRUBS:

AMELANCHIER SP
  A. UTAHENSIS KOEHNE
  A. ALNIFOLIA
ARTEMISIA SP
  A. ARBUSCULA NUTT.
  A. CANA PURSH
  A. NOVA A.NELS.
  A. SPINESCENS EATON
  A. TRIDENTATA SUBSP NUTT.
  A. TRIDENTATA TRIDENTATA
  A. TRIDENTATA VASEYANA
  A. TRIDENTATA WYOMINGENSIS
  A. FRIGIDA WILLD.
ATRIPLEX SP
  A. CONFERTIFOLIA (TORR.&FREM.)WATS.
  A. GARDNERI (MOQ)DIETR
CERATOIDES LANATA (PURSH)HOWELL
CHRYSOTHAMNUS SP
  C. NAUSEOSUS (PALL. EX PURSH)BRITT.
  C. VISCIDIFLORUS (HOOK.)NUTT.
GRAYIA SPINOSA (HOOK.)MOQ.
MAHONIA REPENS (LINDL.)G.DON
POPULUS TREMULOIDES MICHX.
PURSHIA TRIDENTATA (PURSH)DC
ROSA SP
  R. WOODSII LINDL.
SARCOBATUS VERMICULATUS (HOOK.)TORR.
SYMPHORICARPOS SP
  S. OREOPHILUS GRAY
TETRADYMIA SP
  T. CANESCENS DC
  T. NUTTALLII T.&G.

ANNUAL FORBS:

ANDROSACE SP
  A. SEPTENTRIONALIS L.
ATRIPLEX SP
  A. ROSEA L.
BASSIA HYSSOPIFOLIA (PALL.)KUNTZE
BRACHYACTIS SP (WEED)
CHENOPODIUM SP
  C. ALBUM L.
CLEOME SERRULATA PURSH
COLLINSIA SP
  C. PARVIFLORA LINDL.
COLLOMIA SP
  C. LINEARIS NUTT.
DESCURAINIA SP
  D. SOPHIA (L.)WEBB EX PRANTL
DRABA SP
  D. NEMOROSA L.
GILIA SP
  G. TWEEDII RYDB.
HALOGETON GLOMERATUS (BIEB.)MEYER
HELIANTHUS SP
  H. ANNUUS L.
IVA SP
  I. AXILLARIS PURSH STATEWIDE
LACTUCA SP
  L. SERRIOLA L.
LAPPULA SP
  L. MYOSOTIS WOLF
  L. REDOWSKII (HORNEM.)GREENE
LEPIDIUM SP
  L. PERFOLIATUM L.
MENTZELIA SP
  M. DISPERMA WATS.
MONOLEPIS SP
  M. NUTTALLIANA (SCHULTES)GREENE
NAVARRETIA SP
  N. BREWERI (GRAY)GREENE
NICOTIANA SP
  N. ATTENUATA TORR. EX WATS.
ORTHOCARPUS SP
  O. LUTEUS NUTT.
  O. TOLMEI HOOK.&ARN.
PHACELIA IVESANA TORR. EX IVES
PLAGIOBOTHRYS SP
  P. SCOULERI (H.&A.)JOHNST.
POLYGONUM SP
  P. AVICULARE L.
  P. DOUGLASII GREENE
  P. SAWATCHENSE SMALL
SALSOLA KALI L. = S. IBERICA L.
SISYMBRIUM SP
  S. ALTISSIMUM L.
SOLANUM SP
  S. TRIFLORUM NUTT.
SONCHUS ASPER (L.)HILL.
THLASPI SP
  T. ARVENSE L.
TRAGOPOGON SP
  T. DUBIUS SCOP.
VERONICA BILOBA L.

PERENNIAL FORBS:

ACHILLEA MILLEFOLIUM L.
AGOSERIS GL.
ALLIUM SP
A. GEYERI WATS.
A. TEXTILE NELS.&MACBR.
ANTENNARIA SP
A. DIMORPHA(NUTT.)T.&G.
A. MICROPHYLLA RYDB.
ARABIS SP
A. DRUMMONDII GRAY
A. HOLBOELLII HORNEM.
A. NUTTALLII ROBINS.
ARENARIA SP
A. CONGESTA NUTT.
A. HOOKERI NUTT.
A. KINGII (WATS.)JONES
ARTEMISIA SP
A. FRIGIDA WILLD.
ASTER SP
A. GLAUCODES BLAKE
ASTRAGALUS SP
A. AGRESTIS DOUGL. EX E.DON.
A. DIVERSIFOLIUS GRAY
A. JEJUNUS WATS.
A. LENTIGINOSUS DOUGL. EX HOOK.
A. MISER DOUGL. EX HOOK.
A. PURSHII DOUGL. EX HOOK.
A. SPATULATUS SHELD.
BALSAMORHIZA SAGITTATA (PURSH)NUTT.
CALOCHORTUS NUTTALLII T.&G.
CARDUUS SP
C. NUTANS L.
CASTILLEJA SP
C. CHROMOSA A.NELS.
C. LINARIAEFOLIA BENTH.
C. SULPHUREA RYDB.
CHAENACTIS DOUGLASII (HOOK.)
CIRSIUM SP
C. ARVENSE (L.)SCOP.
C. SUBNIVEUM RYDB. TETON&SUBLETTE
COMANDRA UMBELLATA (L.)NUTT.
CORYALIS AUREA
CORDYLANTHUS SP
C. RAMOSUS NUTT. EX BENTH
CRYPTANTHA AP
C. FLAVOCULATA (A.NELS.)PAYSON
C. TORREYANA (GRAY)GREENE
CYMOPTERUS SP
C. BULBOSUS A.NELS.
DELPHINIUM SP
D. NUTTALLIANUM PRITZ. EX WALPERS.
EPILOBIUM SP
E. PANICULATUM NUTT. EX T.&G.
ERIGERON SP
E. CORYMBOSUS NUTT.
E. NANUS NUTT.
E. PUMILUS NUTT.
ERIOGONUM SP
E. BREVICAULE NUTT.
E. HERACLEOIDES NUTT.
E. MICROTHECUM NUTT.
E. OVALIFOLIUM NUTT.
E. UMBELLATUM TORR.
ERYSIMUM SP
E. ASPERUM (NUTT.)DC
E. CHEIRANTHOIDES L.
FRASERA SPECIOSA DOUGL. EX GRIESB.
FRITILLARIA SP
F. ATROPURPUREA NUTT.
F. PUDICA (PURSH)SPRENG.
GENTIANA SP
G. AFFINIS GRIESB.
GERANIUM SP
G. VISCOSISSIMUM FISCH.&MEYER
GEUM SP
G. TRIFLORUM PURSH
GRINDELIA SQUARROSA
HACKELIA SP
H. FLORIBUNDA (LEHM.)JOHNST.
HAPLOPAPPUS SP
H. ACAULIS (NUTT.)GRAY
H. CARTHAMOIDES
HEDYSARUM BOREALE NUTT.
HELIANTHELLA SP
H. UNIFLORA (NUTT.)T.&G.
HEUCHERA SP
H. PARVIFOLIA NUTT. EX T.&G.
HYMENOXYS SP
H. TORREYANA (NUTT.)PARKER
IPOMOPIS SP
I. AGGREGATA (PURSH)GRANT
I. CONGESTA (PURSH)GRANT
LEPTODACTYLON PUNGENS (TORR.)NUTT.
LEWISIA SP
L. REDIVIVA PURSH.
LINUM SP
L. LEWISII PURSH
LITHOPHRAGMA SP
L. GLABRUM NUTT.
LITHOSPERMUM SP
L. RUDERALE DOUGL. EX LEHM.
LOMATIUM SP
L. LEPTOCARPUM (T.&G.)COULT.&ROSE
L. MACROCARPUM (H.&A.)COULT.&ROSE
LUPINUS SP
L. SERICEUS PURSH.
MACHAERANTHERA SP
M. CANESCENS (PURSH)GRAY

M. COMMIXTA GREENE
M. GRINDELIOIDES (NUTT.)SHINNERS
MELILOTUS SP
M. OFFICINALIS (L.)PALL.
MERTENSIA SP
M. VIRIDIS (A.NELS.)A.NELS.
MICROSERIS SP
M. NUTANS (HOOK.)SCHULTZ-BIP.
OENOTHERA SP
O. CAESPITOSA NUTT.
OROBANCHE SP
O. FASCICULATA NUTT.
OXYTROPIS SP
O. SERICEA NUTT.
PENSTEMON SP
P. CYANANTHUS HOOK.
P. HUMILIS NUTT. EX GRAY
P. PROCERUS DOUGL. EX GRAH.
P. RADICOSUS A.NELS.
P. RYDBERGII A.NELS.
PHLOX SP
P. HOODII RICHARDS
P. LONGIFOLIA NUTT.
P. MULTIFLORA A.NELS.
POTENTILLA SP
P. ARGUTA PURSH
P. GLANDULOSA LINDL.
RANUNCULUS SP
R. CYMBALARIA PURSH
R. GLABERRIMUS HOOK.
RUMEX SP
R. SALICIFOLIUS WEINM.
SEDUM SP
S. LANCEOLATUM TORREY
SENECIO SP
S. INTEGERRIMUS NUTT.
S. MULTILOBATUS T.&G. EX GRAY
SIDALCEA SP
S. OREGANA (NUTT. EX T.&G.)GRAY
SILENE SP
S. MENZIESII HOOK.
SISYMBRIUM SP
S. LINIFOLIUM (NUTT.)NUTT. EX T.
SPHAERALCEA SP
S. COCCINEA (NUTT.)RYDB.
S. MUNROANA DOUGL. EX LINDL.
STANLEYA SP
S. VIRIDIFLORA NUTT.
STEPHANOMERIA SP
S. RUNCINATA NUTT.
STREPTANTHUS SP
S. CORDATUS NUTT.
TARAXACUM OFFICINALE WEBER
TRIFOLIUM SP
T. GYMNOCARPON NUTT.
VIOLA SP
V. PURPUREA KELL.
ZYGADENUS SP
Z. PANICULATUS (NUTT.)WATS.

Table 2.

Plants species found growing on the mined site in 1982

Shrubs
Atriplex gardneri
Artemisia tridentata
*Chrysothamnus vicidiflorus

Perennial Grasses
Agropyron dasystachum
Agropyron smithii
Agropyron spicatum
*Hordeum jubatum
Hordeum vulgare
*Oryzopsis spp.
*Poa spp.
Sitanion hystrix

Annual Grasses
Bromus japonicus
*Bromus tectorum

Perennial Forbs
Allium spp.
Arenaria congesta
Chaenactis douglasii
Cirsium subniveum
Cryptantha torreyana
*Epilobium paniculatum
*Epilobium spp.
*Eriogonum brevicaule
Gilia tweedii
Hedysarum boreale
Lithospermum spp.
Sphaeralcea munroana

Annual Forbs
*Atriplex rosea
Brachyactis spp.
*Chenopodium album
Chenopodium spp.
*Collinsia parviflora
Collinsia spp.
*Descurania sophia
*Halogeton glomeratus
*Lactuca serriola
*Lappula redowskii
Lepidium perfoliatum
Mentzelia disperma
*Monolepis nuttalliana
Navarretia breweri
Orthocarpus spp.
Orthocarpus tolmei
Phacelia ivesana
*Polygonum aviculare
Polygonum sawatchwense
*Salsola iberica
Sonchus asper
*Thlaspi arvense
Tragopogon dubius
Veronica biloba

* Species with seeds found in seed traps.

Table 3.
Occurence of seeds in seed traps during fall 1982 orspring 1983

	Location*					
	1	2	3	4	5	6
Shrubs						
Artemisia tridentata	X					
Chrysothamnus nauseosus	X					
Chrysothamnus viscidiflorus	X	X				X
Perennial Grass						
Hordeum jubatum			X			X
Hordeum spp.			X			X
Melica bulbosa						X
Oryzopsis hymenoides	X		X			X
Poa spp.	X		X		X	X
Annual Grass						
Bromus tectorum	X	X	X	X	X	X
Perennial Forbs						
Arabis holboellii	X					
Arabis spp.			X			
Arenaria congesta	X					
Epilobium paniculatum	X	X	X			X
Epilobium spp.	X		X	X		
Eriogonum spp.	X		X	X		X
Oenothera spp.			X			
Oxytropis spp.	X					
Rumex salicifolius			X			
Sphaeralcea coccinea		X	X			
Taraxacum officinale		X				
Trifolium gymnocarpum	X					
Trifolium spp.	X					
Annual Forbs						
Atriplex rosea	X	X	X	X	X	X
Atriplex spp.						X
Chenopodium album	X	X	X	X	X	
Collinsia parviflora	X	X	X			X
Descurania sophia			X	X		
Halogeton glomeratus	X	X	X	X	X	X
Lactuca serriola		X	X	X	X	
Lappula redowskii	X		X		X	X
Monolepis nuttalliana	X	X	X	X	X	X
Polygonum aviculare	X	X	X	X	X	X
Polygonum douglasii		X	X	X	X	
Salsola iberica	X	X	X	X	X	X
Thlaspi arvense		X	X		X	

*
1- west native area
2- west slope of west ridge
3- east slope of west ridge
4- west slope of east ridge
5- east slope of east ridge
6- east native area

Table 4.

Plant species with seeds on the mined site in 1982

Shrubs

XChrysothamnus viscidiflorus

Perennial Grasses

#Hordeum jubatum
#Oryzopsis hymenoides
#Poa Sandbergii

Annual Grasses

Bromus tectorum

Perennial Forbs

*Arabis spp.
#Epilobium paniculatum
#Eriogonum spp.
*Oenothera spp.
*Rumex salicifolius
*Sphaeralcea coccinea
*Taraxacum officinale

Annual Forbs

Atriplex rosea
Chenopodium album
Collinsia parviflora
Descurania sophia
Halogeton glomeratus
Lactuca serriola
Lappula redowskii
Monolepis nuttalliana
Polygonum aviculare
*Polygonum douglasii
Salsola iberica
Thlaspi arvense

X Species planted on the mined site.

* Species not found growing on the mined site.

Species growing on the mined site, but seed assumed to have come from off the mined site.

Table 5. Average number of seeds (m^{-2}) from each species found in seed traps in the fall of 1982 and the spring of 1983 for each of six locations with standard error of means in partheses.*

Species	West native area	West slope of west ridge	East slope of west ridge	West slope of east ridge	East slope of east ridge	East native area
Artemisia tridentata	300.24(131.76)					
Chrysothamnus nauseosus	80.35(63.94)					
Chrysothamnus viscidiflorus	8.46(2.99)	82.51(61.44)				
Hordeum jubatum			61.93(55.17)			41.64(32.04)
Oryzopsis hymenoides	101.49(73.12)		2.29(2.29)			10.41(10.40)
Poa scabrella	279.10(133.87)		768.34(696.18)		5.64(5.64)	10.41(10.40)
Bromus tectorum	54.97(24.93)	9.90(5.57)	103.21(39.72)	190.29(126.20)	45.11(15.59)	
Arabis holboellii	4.23(4.23)		2.29(2.29)			
Arenaria congesta	12.69(9.33)					
Epilobium paniculatum	228.35(132.69)	4.23(3.74)	82.57(38.30)		10.83(7.65)	10.41(10.40)
Eriogonum spp.	4.23(3.23)		45.87(19.25)	4.23(4.23)		145.73(134.69)
Oenothera spp.			2.29(2.29)			
Oxytropis spp.	4.23(4.23)					
Rumex salicifolius			4.58(4.59)			

Table 5 (cont.)

Species	West native area	West slope of west ridge	East slope of west ridge	West slope of east ridge	East slope of east ridge	East native area
Sphaeralcea coccinea		3.30(3.30)	4.59(3.22)			
Traxacum officinale		3.30(3.30)				
Trifolium gynocarpum	8.46(5.88)					
Atriplex rosea	131.09(87.89)	132.02(87.50)	144.49(42.28)	8.46(5.88)	78.94(34.47)	41.64(32.04)
Atriplex spp.						124.91(124.76)
Chenopodium album	104.73(296.78)	161.72(91.70)	146.79(58.74)	16.92(10.07)	16.92(12.38)	
Collinsia parviflora	152.24(87.11)	49.51(29.81)	34.40(11.61)			
Descurania sophia			3272.91(2250.66)	4.23(4.23)		
Halogeton glomeratus	38.06(25.93)	2003.40(1916.77)	277.52(141.28)	177.61(59.33)	236.81(96.79)	62.46(52.16)
Lactuca serriola		6.60(6.60)	444.95(169.23)	9.93(9.93)		
Lappula redowskii	114.18(72.90)		20.64(10.25)		5.64(5.64)	20.82(20.79)
Melilotus officinalis						20.82(20.79)
Monolepis nuttalliana	71.89(38.40)	29.70(12.96)	100.92(32.16)	12.69(7.08)	73.30(23.00)	239.41(168.44)
Polygonum aviculare	122.63(40.01)	39.61(18.46)	1866.96(686.80)	126.86(72.35)	1031.82(897.68)	10.41(10.40)
Polygonum douglasii		3.30(3.73)			5.64(5.64)	
Salsola iberica	71.89(21.88)	858.13(172.59)	2194.94(548.38)	740.03(178.19)	7410.12(2302.97)	458.01(252.63)
Thlaspi arvense		3.30(3.30)	4.59(3.22)	215.67(215.55)	73.30(73.28)	

* Data were collected as #seeds/seed trap (seed trap area = 177cm^2) and were converted to #seeds m^{-2}.

Figure 1. Seed trap design.

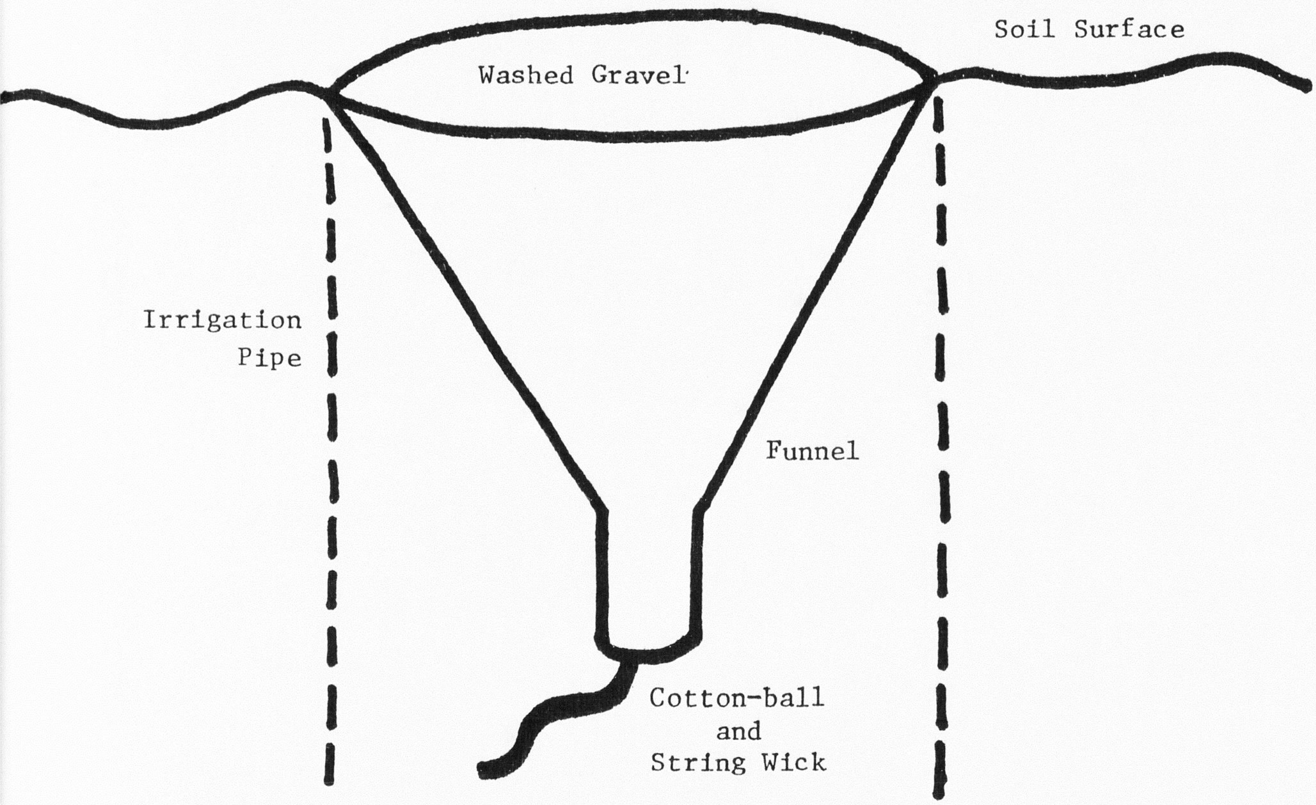
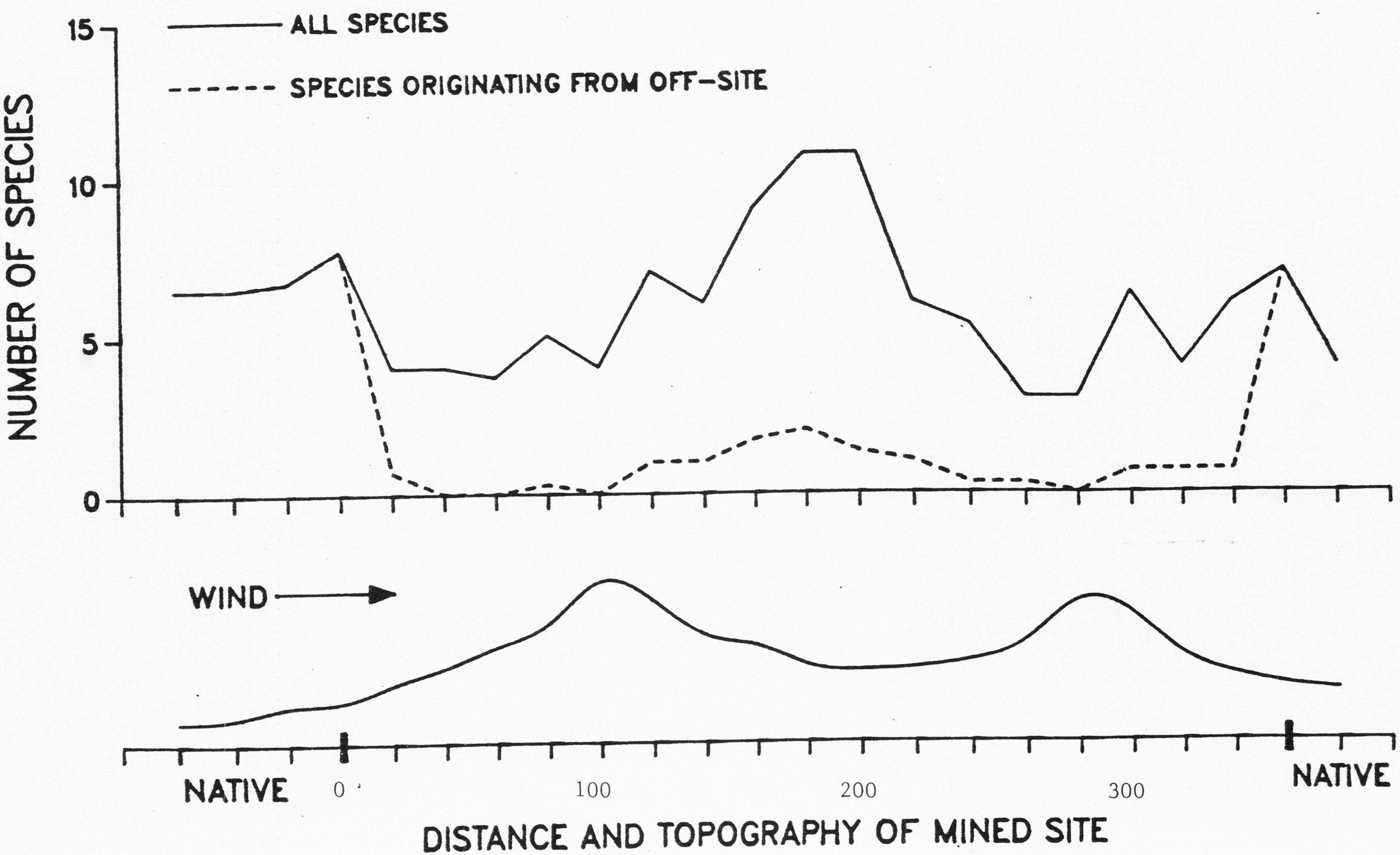


Figure 2.

Seed rain dispersion patterns on 12-U-C for seed produced in summer 1982.



(distance in m)

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